NATIONAL ACADEMY OF SCIENCES

Number 42 • December 1960

IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

UNIVERSITY OF ILLINOIS LIBRARY APR 6 1961 CHICAGO

Solar Radiation Satellite

The following material is based on a report by T. A. Chubb, H. Friedman, R. W. Kreplin, W. A. Nichols, A. E. Unzicker, and M. J. Votaw, of the US Naval Research Laboratory. The experiment, of interest to geophysicists and solar physicists, was carried out in a "piggyback" satellite launched with Transit II-A, a Navy vehicle.

The United States Naval Research Laboratory's Solar Radiation Measuring Satellite, or "Sunray," launched from Cape Canaveral, Florida, at 1:54 am EDT on June 22, 1960, is transmitting the first continuous measurements of solar activity in terms of the sun's X-ray and ultraviolet radiations. Sunray was carried into orbit clamped to the Transit II-A navigational satellite, from which it was disconnected by a spring device about 30 minutes after launch and ejected into a separate orbit. The Sunray satellite, designated 1960 Eta 2 (Transit II-A is 1960 Eta 1), is, in fact, an orbiting elementary solar observatory.

Solar ultraviolet and X-ray radiations are responsible for the formation of the ionosphere of the earth. These radiations are variable and produce day-to-day and seasonal changes in ion density and, during solar flares, sudden ionospheric disturbances that seriously disrupt long-range radio communication and navigation systems. When satellites have collected enough data on these radiations, much more will be

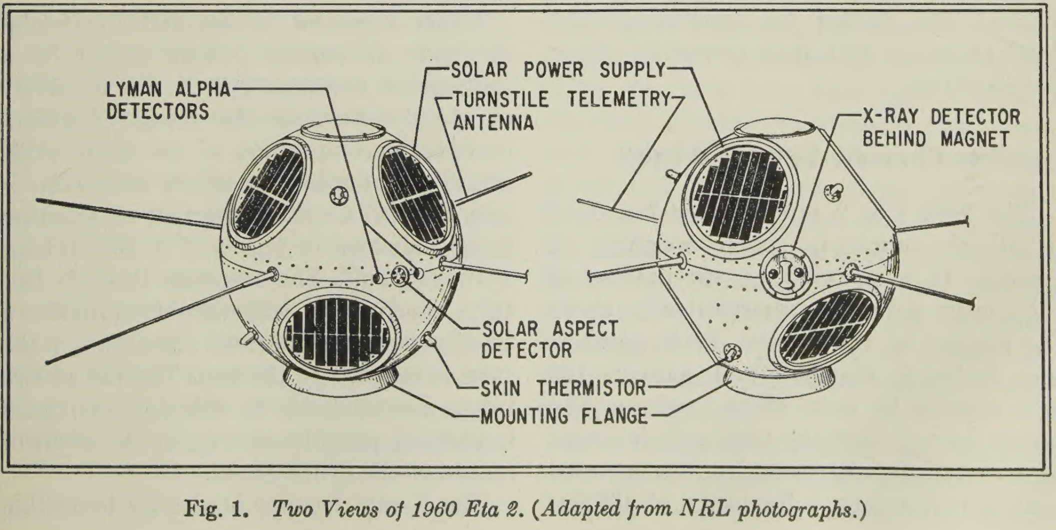

Fig. 1. *Two Views of 1960 Eta 2. (Adapted from NRL photographs.)*

known about ionospheric behavior and it may then be possible to improve predictions of the range of short-wave communications.

Much of the most recent knowledge about solar X-ray and ultraviolet radiations has been acquired through rocket-astronomy experiments. The Naval Research Laboratory has been conducting such experiments at intervals since 1949. Two examples of knowledge gained through these solar rocket-astronomy studies are the finding that X-rays streaming from the sun are generated primarily in the sun's corona, and that the sky is covered with still-unexplained blotches of ultraviolet radiation.

Although very significant, information from rocket experiments has been limited by the brevity of rocket observation periods (about six minutes per rocket flight), by the relatively small number of rockets that can be instrumented and flown each year, and by the variability in rocket and instrument behavior from one flight to the next. These limitations do not apply to a solar-satellite-photometry experiment, however, because of the comparatively long and continuous observation period (up to a year or more in the NRL Sunray experiment) made possible with a single instrument package in orbit. Thus, the 1960 Eta 2 experiment is expected to provide, for the first time, a reliable time history of solar radiations and to yield the kind and quantity of data long desired and needed for correlating these solar emissions with their terrestrial atmospheric effects.

Satellite Characteristics and Orbit

The 1960 Eta 2 satellite (see Fig. 1) is a 20-inch aluminum sphere weighing 42 pounds. It is powered by six patches of solar cells arranged symmetrically about the surface of the sphere. Each patch is nine inches in diameter and contains 156 cells covered by fused silica windows. The power derived from the solar cells is stored in nickel cadmium batteries. Telemetered data is radiated on a frequency of 108.000 mc/sec from four 25-inch tubular antennas protruding from the satellite's equator 90° apart. It is tentatively planned to continue the experiment for one year, when the transmitter may be turned off by radio command.

Once every 101.5 minutes, 1960 Eta 2 completes an orbit with a 657-mile apogee and a 382-mile perigee, and inclined 67.5° to the equator. Examination of records obtained during the first three months since the launch indicates that the experiment is working as planned.

Instrumentation and Measurement Techniques

The Lyman-α ionization chambers are cylindrical in shape, 3.4 cm in diameter and 2.4 cm long. Each chamber is fitted with a lithium fluoride window and filled with nitric oxide (NO) at a pressure of 15 mm of mercury (Hg). The detectors have a quantum yield, or photoelectric efficiency, of the order of 30% and are sensitive to wavelengths between 1040A and 1340A; the first is determined by the transparency of the lithium fluoride and the second by the ionization potential of the nitric oxide gas. In this wavelength range, Lyman-α radiation is the predominant solar emission and contributes all but 10% of the ion-chamber response.

Under exposure to the full ultra-violet spectrum of sunlight, there would be a progressive deterioration of the efficiency of the detectors as the result of photochemical decomposition of the nitric oxide gas. To minimize this effect, each tube is covered with a mask containing an aperture having an area of only 9.4×10^{-5} (about 1/10,000) cm^2. The response through this tiny aperture is sufficient to provide a readily measured current signal when the tube is exposed to the sun. The use of two tubes, mounted side by side and connected in parallel, provides backup in the event of failure of one of the tubes.

The X-ray detector is also an ionization

chamber. It contains a beryllium window with a surface density of 0.025 gm/cm^2 and an open area of 2.33 cm^2. The absorbing gas is argon at a pressure of 760 mm Hg. Depth at normal incidence is 2.54 cm.

Maximum efficiency of the X-ray detector, 76%, occurs at 2.8A. The X-ray chamber is mounted on the equator of the satellite behind the gap of a permanent magnet having a field strength of about 3000 gauss. The magnet gap is 3/8 of an inch wide and one inch square in cross-section. The magnet serves as a "broom," preventing the passage of low-energy electrons of the Van Allen radiation belt with nearly 100% effectiveness for energies below 0.5 mev.

Parallel to the Lyman-α detectors is a photocell sensitive to visible light. The photocell signals are used to determine the angle between the satellite's spin axis and the sun. This information is necessary to correct the responses of the ionization chambers with respect to the satellite's position relative to that of the sun.

Telemetry

A 10-channel AM-FM telemetry system using a carrier frequency of 108.00 mc/sec transmits the Lyman-α, X-ray, and solar-aspect data. Radiated power is 30 mw. To receive and de-modulate the solar-radiation data at a ground station requires a receiver of approximately 8-kc bandwidth. The detected output of the receivers is recorded on magnetic tape simultaneously with real-time signals.

A solar aspect signal produces a positive going pulse once each roll of the satellite, or about every 10 seconds. The peak amplitude of the aspect pulse is determined by the angle betwen the sun and a normal to the spin axis of the satellite. A Lyman-α signal produces a negative pulse once each roll of the satellite, and an X-ray signal produces a positive pulse once each roll but displaced in time by 180° of roll from the Lyman-α pulse.

At present, signals from the satellite are being received and recorded by Minitrack stations at Blossom Point, Maryland, Lima, Peru, Santiago, Chile, and Woomera, Australia. Tapes are sent to NRL for data reduction. The duration of reception during any given pass of the satellite depends on its altitude and latitude relative to the ground station. Under the best conditions good signal-to-noise ratio is obtained for as long as 15 minutes and, on the average, telemetry reception is good for 7 or 8 minutes.

Experimental Results

On August 6, 1960, data were received during a pass by 1960 Eta 2 over Blossom Point, Maryland, simultaneously with a Class 1 solar flare that lasted 18 minutes. The flare began just as the satellite came within range of the station, and six minutes of clear signal reception showed the history of development of ultraviolet and X-ray emission in relation to ionospheric behavior and to solar-radio noise.

One minute after the start of the visible flare, short-wave radio signals began to fade; two minutes later, cosmic radio noise began to fade. At this point, the satellite signals clearly showed an increase in the intensity of solar X-rays. One minute later, the sun began to emit a strong radio-noise burst at 2800 mc/sec. The noise burst persisted for two minutes, during which the X-ray flux rose to a very high level and remained intense even after the radio-noise burst had disappeared. When the satellite passed out of reception range, the X-ray flux was still strong, but on the satellite's next transit, two hours later, the sun was again completely calm and there was no indication of abnormal X-ray emission. Throughout this sequence of events the sun's ultraviolet radiation remained completely unchanged.

As it continues to measure and transmit solar Lyman-α and X-ray emissions, the satellite should contribute many new records

of solar activity. Since the value of the experiment would be greatly enhanced by broader telemetry-reception coverage along its orbit, efforts are under way to expand the ground-station network from the original four stations to perhaps ten. By combining and overlapping the observations of a number of stations, it should be possible to obtain the full time history of the X-ray and Lyman-α variations accompanying a wide variety of solar activity in the optical and radio spectra.

Additional Information

The Naval Research Laboratory welcomes participation in this experiment by scientists outside the United States. The information contained above, along with that added below for this purpose, permits any interested scientist to reduce telemetry data from 1960 Eta 2 to X-ray and ultraviolet intensities. At any individual site it should be possible to capture portions of many interesting solar events during the course of several months' observation.

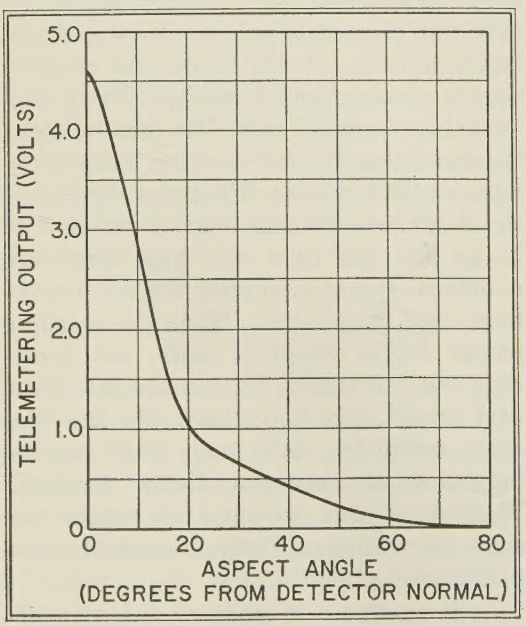

Fig. 2. *Calibration Curve for Solar-Aspect Photocell.*

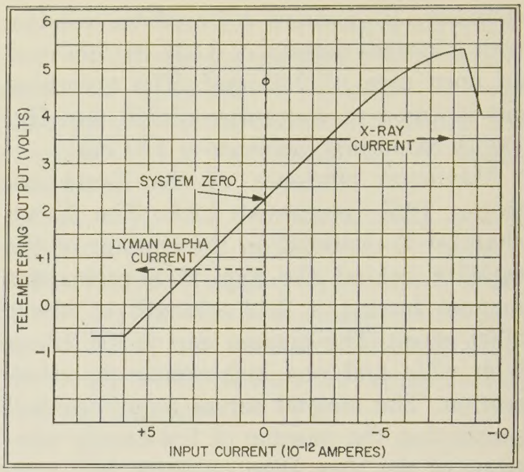

Fig. 3. *Calibration Curve for Lyman-α and X-ray Sensors. Ionization current is shown as a function of telemetered voltage.*

In the telemetry system, two standard IRIG FM sub-carrier oscillators amplitude modulate the RF carrier. The Lyman-α and X-ray data are both on channel 6, center frequency 1700 cycles per second, $\pm$ 7.5% deviation. The aspect data is on channel 5, center frequency 1300 cps, $\pm$ 7.5% deviation.

The magnetic tape on which data are recorded at the ground stations is played back into two FM sub-carrier discriminators, channels 5 and 6, with the output of the discriminators feeding a two-channel paper recorder capable of writing 80 to 100 cps. The real-time signal is also recorded simultaneously.

Channel 5, the aspect channel, has a zero signal level of about 0.3 volts. Two voltage calibration points are transmitted once every eight seconds; the first point represents + 3.9 volts and is followed by a zero volt point, one second later. The relationship between the aspect-pulse voltage at peak amplitude and the solar-aspect angle is not linear. In the range 4.6-1.3 volts, the angle varies from 0° to 20°; from 1.0 to 0.4 volts, the angle varies from 20° to 60° (see Fig. 2).

Channel 6 has a zero signal level of 2.4 $\pm$ 0.1 volts (Fig. 3). As in channel 5, two voltage calibration points are transmitted,

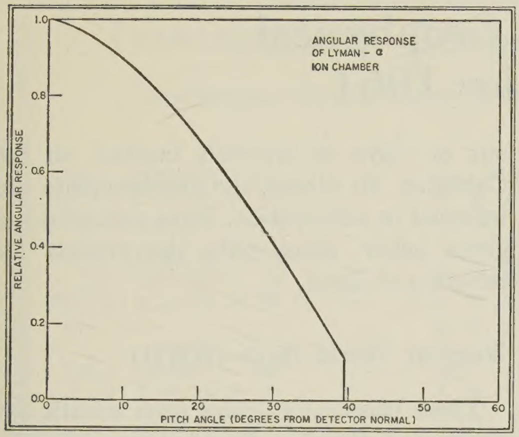

Fig. 4. *Relative-Sensitivity Correction Factor for Lyman-α Detector as a Function of Pitch Angle.*

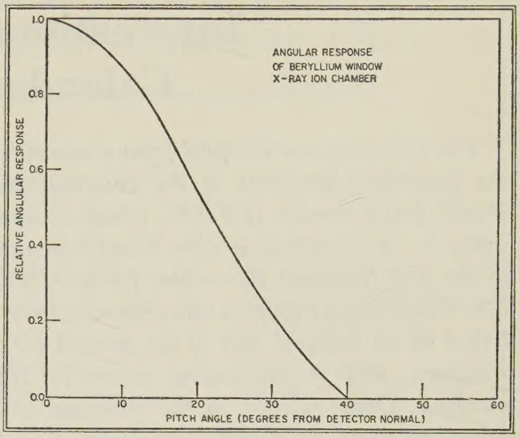

Fig. 5. *Relative-Sensitivity Correction Factor for X-ray Detector as a Function of Pitch Angle.*

but the order is reversed. The zero voltage calibration point occurs first, followed in one second by a + 4.0 volt point.

The peak amplitude of the Lyman-α or X-ray signal is measured on a linear scale in reference to the zero volt and 4-volt calibration points. After converting the peak voltages of the Lyman-α and X-ray pulses to detector current (Fig. 3), a correction is made for the aspect angle (Figs. 4 and 5). The corrected current is then converted to Lyman-α or X-ray intensity in ergs/cm^2/sec. For Lyman-α, the conversion factor is 1.5×10^{12} ergs/cm^2/sec/amp. To convert the X-ray signal to intensity in ergs/cm^2/sec, reference is made to Figure 5 and to the efficiency curve of Figure 6. A true conversion is possible only if the X-ray wave-length distribution is known. Rocket experiments have shown that the X-ray flux declines rapidly as the quantum energy increases. The response of the X-ray detector is, therefore, heavily weighted toward the longer wavelengths and the appropriate factor for most flares would be in the neighborhood of 2.7×10^8 ergs/cm^2/sec/amp.

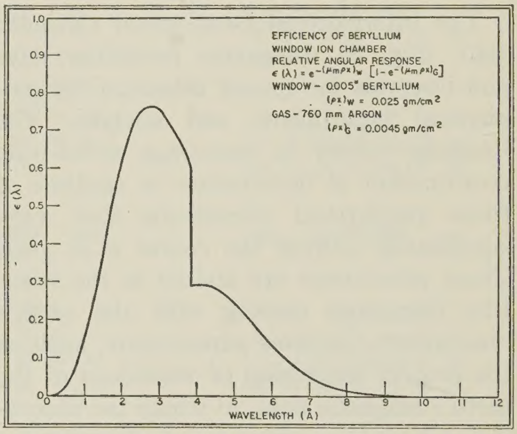

Fig. 6. *Spectral Efficiency of X-ray Ion Chamber.*

International Geophysical Calendar for 1961

The following was adapted from a report by the Steering Committee of the International World Days Service (IWDS), whose spokesman, A. H. Shapley, is also Vice-Chairman of the US National Committee for the IGY. The World Days Program was originally established as an integral part of the over-all IGY Program, and is continuing under IWDS auspices. Other reports on the structure and organization of the World Days Program, including Geophysical Calendars for the IGY and IGC-1959 periods and for 1960, appeared in Bulletin Nos. 2, 5, 23, *and* 29.

The International Geophysical Calendar 1961 (Fig. 8) designates particular days and intervals for special attention for geophysical experiments and analysis. The Calendar serves to encourage world-wide coordination of observation or analysis of those geophysical phenomena that vary significantly during the course of a year. These phenomena are mainly in the scientific disciplines dealing with the earth's atmosphere. In some experiments, such as the routine measuring of variations of the earth's magnetic field, in which the observing and analysis programs at observatories are carried out at a uniform level throughout the year, the Calendar is not needed. However, in many other experiments (rocket experiments, for example), it is not practical or meaningful to carry out the same program on each and every day, and the Calendar can thus provide a useful mechanism for coordination. Experimenters know that their colleagues in other laboratories and in other disciplines also tend to carry out experiments on the days or intervals marked on the Calendar. In this way, results of experiments may be more easily and usefully compared.

In some scientific fields, international scientific organizations have made specific recommendations for programs to be carried out on days or intervals marked on the Calendar. In others, the arrangements are informal or self-evident. Some examples are given below, along with the criteria for selection of dates.

Regular World Days (RWD)

Three consecutive days each month are designated Regular World Days (RWD). RWD always come in the middle, or just after the middle, of the month and include, when possible, the times of equinox and solstice. RWD come in the middle of the week for which they are scheduled— Tuesday, Wednesday, and Thursday— and the three-day groups of RWD are evenly spaced through the year, so far as it is practical. One RWD each month (always Wednesday) is given highest priority, and, whenever possible, RWD include days of solar eclipse and meteor showers.

The RWD are intended for experiments or for observational or analysis programs which, as a practical matter, can be carried out only about 10% of the time and which, for maximum usefulness, should be spaced more-or-less evenly through the year. Further, it is suggested that whenever there are no special reasons for selecting other days, RWD be used for unusual or special experiments. This applies in particular, perhaps, to investigations in atmospheric geophysics, including aspects of cosmic rays, meteorology, airglow, ionosphere, geomagnetism, and aeronomy. Some examples in ionospheric physics are (1) oblique-incidence pulse transmission and reception; (2) absorption measurements by the pulse-reflection technique; (3) extended observing schedules for whistlers and other VLF emissions; (4) vertical-soundings on a faster-than-normal schedule; (5) more-detailed reduction of vertical-sounding ionograms by f-plot, h′-plot, etc.; and (6) hourly reduction

International Geophysical Calendar 1961

Issued November 1960 by the International World Day Service under the auspices of U. R. S. I.

1961 JANUARY 1961

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
* 22	23	24	25	26	27	28
29	30	31				

1961 FEBRUARY 1961

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18 * *
19	20	21	22	23	24	25
26	27	28				

1961 MARCH 1961

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

1961 APRIL 1961

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

1961 MAY 1961

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

1961 JUNE 1961

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

1961 JULY 1961

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

1961 AUGUST 1961

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

1961 SEPTEMBER 1961

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

1961 OCTOBER 1961

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
* 22	23	24	25	26	27	28
29	30	31				

1961 NOVEMBER 1961

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

1961 DECEMBER 1961

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

1962 JANUARY 1962

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

17 Regular World Day (RWD)

18 RWD with highest priority

21 Day with unusual meteor shower activity

15 Day of solar eclipse

16 17 18 19... World Meteorological Interval (WMI)

14 15 16 17... Regular World Interval (RWI)

(12 13 14 15...) International Rocket Week (IRW)

Notes : (*) WMI in January and October considered most important

(* *) Feb. 15, 1961 : RWD with highest priority

Fig. 8. *Geophysical Calendar for 1961.*

from ionograms of F-region true-height parameters "hc" and "qc."

The highest-priority RWD are for work that can be undertaken for only one day each month. All of the foregoing examples can also be included in the highest-priority category if the rate of three days per month is not necessary or proves to be too heavy. A specific example is the program for 1959 and onwards regarding exchange of copies

of original ionograms in ionospheric vertical-sounding work: the URSI-AGI Committee has recommended that ionograms for the highest-priority RWD each month (and also for one disturbed period each year) be sent to World Data Centers for interchange.

Regular World Intervals (RWI)

Ten consecutive days in each quarter year, selected to include the three RWD of the month in which they are scheduled and the times of the equinox or solstice, are designated Regular World Intervals (RWI). If possible they also include days of solar eclipses and meteor showers, and avoid weekend days and widely observed holidays.

The RWI are intended for experiments that, for practical reasons, cannot be carried on continuously, but for which statistical data on seasonal variations are especially needed. Ionospheric drift and high-atmosphere wind measurements are two examples. Schedules for interchange of sample detailed data in several disciplines have made use of RWI and, in some network observational programs, both RWI and RWD are used to obtain both the variations occurring throughout the year and improved statistical data at the equinoxes and solstices.

World Meteorological Intervals (WMI)

In each quarter, 10 consecutive days displaced one month from the equinoxes and solstices have been designated World Meteorological Intervals (WMI). These intervals are intended to cover the times of marked seasonal change in certain meteorological phenomena, which tend to occur about a month after the equinoxes and solstices. WMI have been chosen through World Meteorological Organization (WMO) and Committee on Space Research (COSPAR) channels as the 16th through the 25th of January, April, July, and October, with January and October designated by COSPAR as the more important ones.

WMI now are primarily periods for carrying out synoptic meteorological rocket programs, with participating stations obtaining atmospheric profiles up to 50 kilometers or more at least once daily during each of the 10-day intervals. WMI have also been used during and since the IGY for balloon-sounding programs involving either special instruments or launchings to unusually high altitudes.

International Rocket Weeks (IRW)

International Rocket Weeks (IRW) for 1961 have been scheduled by COSPAR for (I) February 12–18 and (II) July 16–22. IRW-I will include the total solar eclipse of February 15 and is intended for study of solar-terrestrial effects. IRW-II was selected for study of summer atmospheric structure in the northern hemisphere.

The IRW provide two periods during the year when rocket studies of the atmosphere and of the sun will be on as nearly synoptic a basis as possible at this stage of development of the science and technology concerned. More-detailed recommendations by Working Group 2 of COSPAR, J. Bartels, Chairman, appear in the *COSPAR Information Bulletin.*

Other Special Days

The 1961 Calendar marks the days of solar eclipses—February 15 (total) and August 11 (annular). Some special programs may be expected to be carried out in appropriate parts of the world to study eclipse effects on the earth's atmosphere. It is especially important that the record of solar activity during and near times of eclipses be as full as possible. Many solar-activity observatories therefore issue especially detailed reports of their observations on eclipse days in order to assist in the interpretation of the associated geophysical measurements. Ionospheric stations customarily increase their observing programs on these days even if the magnitude of eclipse at their locations is small.

Also shown on the 1961 Calendar are days when meteor-shower activity is expected to be unusually high. Geophysicists using meteor techniques often enhance their observing programs on these days. Attention is also called to these days because ionization produced by meteors may account for unusual effects in other geophysical experiments.

Special Intervals Not Appearing on 1961 Calendar

The International Geophysical Calendar marks only those dates that can be selected long in advance, either by general agreement or, as in the case of eclipses and meteor showers, by reliable long-term prediction. Periods of great magnetic, auroral, and ionospheric disturbance are also of great geophysical interest, however, and world-wide coordination of observation is clearly desirable. Such special observational intervals are provided for under the auspices of the International World Day Service, in close collaboration with the URSI (International Scientific Radio Union) Central Committee on URSIgrams in the program for the immediate designation of *Geophysical Alerts* and for selection, on a current basis, of *Special World Intervals* (*SWI*).

Arrangements for receipt of such information by telegram or radio broadcast can be made, as may be practical, with one of the solar-geophysical Regional Warning Centers, whose telegraphic addresses are as follows: (Western Hemisphere) AGIWARN WASHINGTON (USA); (Western Pacific) AGI KOKUBUNJI (Japan); (Eurasia) NIZMIR MOSCOW (USSR); (Western Europe) either IONOSPHARE DARMSTADT (GFR) or GENTELABO PARIS (France) or AGI NEDERHORSTDENBERG (Netherlands).

The meteorological telecommunications network coordinated by WMO carries such information once daily soon after 1600 UT. Description of the GEOALERT and SWI plan can be obtained from these centers or from the IWDS Secretary. Many geophysical stations increase their programs or carry on special experiments during disturbed periods; the GEOALERT and SWI program serves to coordinate this on a world-wide basis and is especially useful for stations not near the auroral zones and at which, consequently, the beginning of a major disturbance may not be immediately apparent from local observations.

The IWDS, in close collaboration with the URSI Central Committee on URSIgrams, also promotes arrangements for prompt notification, through the Regional Warning Centers, of major solar-flare events, which have important and sometimes long-lasting geophysical effects.

Calendar Records

A summary record of significant solar and geophysical events is being prepared under IWDS auspices as a Calendar Record for the IGY period and for IGC-1959. If these volumes prove useful, similar Calendar Records may be compiled for 1960 and 1961.

Organization of IWDS and Compilation of 1961 Calendar

The International World Day Service (IWDS) was established in 1958 by ICSU and is administered by URSI, 7 Emile Danco, Brussels 18, Belgium. The IWDS Steering Committee consists of A. H. Shapley (URSI), M. Nicolet (International Union of Geodesy and Geophysics—IUGG), and J. F. Denisse (International Astronomical Union—IAU), with R. Coutrez (URSI) as Secretary. A. H. Shapley serves as spokesman for IWDS and as its correspondent to other ICSU groups such as the International Committee on Geophysics (CIG) and COSPAR. IWDS obtains nominal support from the ICSU Federation of Astronomical and Geophysical Services (FAGS).

The International Geophysical Calendar for 1961 was drawn up by A. H. Shapley and J. V. Lincoln in consultation with URSI, IUGG, and IAU, both directly and through CIG and COSPAR. Recommendations also were made by representatives of WMO and from interested individual scientists. A similar Calendar was issued for 1960 along the lines of the calendars for the IGY and IGC-1959, which were issued under the auspices of the ICSU Special Committee for the International Geophysical Year (CSAGI) and described in the "IGY Instruction Manual for World Days and Communications," *IGY Annals*, vol. VII, Pergamon Press, 1959.

Ionosphere Direct Measurement Satellite

The following report is based on material provided by R. E. Bourdeau, Head, Planetary Ionospheres Branch, National Aeronautics and Space Administration. Responsibilities for the experiments included in the satellite are as follows: J. A. Kane—impedence probe; R. E. Bourdeau, G. P. Serbu, and E. C. Whipple, Jr.—ion traps and Langmuir probe; R. E. Bourdeau and J. L. Donley—electric-field meter; and W. M. Alexander, C. W. McCracken, and Otto Berg—micrometeorite experiments. All of the experimenters are with NASA's Goddard Space Flight Center.

Satellite 1960 Xi (Explorer VIII), designed to provide basic information on the ionosphere by direct measurement, was launched from Cape Canaveral, Florida, at 0523 UT, November 3, 1960, and injected into orbit nine minutes later. The 60-ton, 76-foot Juno II launch vehicle was similar to those used to boost the Pioneer IV space probe (see *Bulletin No. 30*) and to put satellite 1959 Iota (Explorer VII) into orbit (see *Bulletin No. 29*).

The satellite is a project of the National Aeronautics and Space Administration, under the management of NASA's Goddard Space Flight Center. NASA's George C. Marshall Space Flight Center prepared the payload, and designed, developed, and launched the Juno II carrier rocket. The scientific experiments were developed and built by the Goddard Center. The NASA Jet Propulsion Laboratory provided the vehicle's three-stage, high-speed upper assembly.

Satellite Characteristics

The configuration of satellite 1960 Xi, like that of 1959 Iota, is in the form of two truncated cones with their bases attached to a cylindrical equator. The satellite is 30 inches in both height and diameter, and the over-all weight in orbit is approximately 90 pounds. The outer shell is constructed of aluminum. (See Figure 9.)

Four thermistors monitor temperatures at the battery case, within the instrument column, in the vicinity of the micrometeorite photomultiplier tube, and on the inside of the satellite skin at the equator.

Orbit

Initial perigee was 258.44 statute miles, apogee was 1422.65 miles; the satellite's period was 112.75 minutes, and an orbital inclination of 49.98° was obtained.

A perigee as low as possible was desired in order to compare the results of the ionosphere experiments with those from the existing worldwide network of ionosphere virtual-height stations. Data from the virtual-height stations are valid only up to F2 maximum, the altitude of which varies from 200 to 300 miles. An apogee

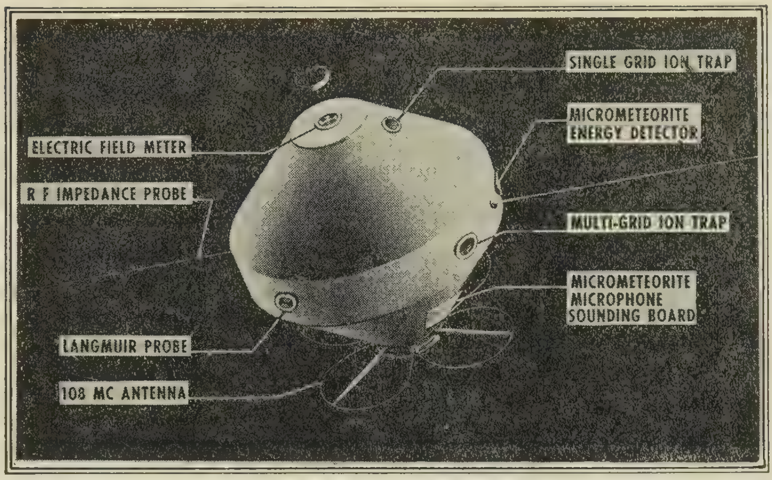

Fig. 9. *Ionosphere Direct Measurement Satellite 1960 Xi (Explorer VIII). (Drawing by NASA.)*

high enough so that the altitude of the base of the exosphere can be determined from the ion mass distribution (ion trap data) was also desired and achieved, and the high orbital inclination permits broad latitude coverage for the ionospheric properties measured. High inclination also permits examination of the micrometeor flux with respect to latitude.

Experimental Objectives

The major objective of 1960 Xi (Explorer VIII) is the study of the temporal and spatial distribution of ionospheric properties, and how they change under such variable conditions as sunlight and shadow. The ionization being investigated consists of particles with low, or thermal, energies, a group that exerts the greatest influence on communications. Results of the measurements may eventually help communications scientists to choose operating frequencies for long-range communications links.

The 1960 Xi ionosphere experiments, unlike those in other NASA-planned ionosphere satellites, do not depend upon radio propagation. Instead, they are all plasma probes that sample the vehicle environment directly, and transmit data over the telemetry link. Plasma probes have two major advantages over propagation methods: (1) they measure a considerably greater number of ionospheric properties and (2) they are much less sensitive to the rapid time variations of ionospheric conditions. On the other hand, the success of the experiments depends upon careful evaluation of the disturbance created in the medium by the presence of the vehicle itself, a factor that does not appreciably affect propagation methods.

The ionospheric properties under study include electron and positive-ion concentrations, electron temperature, and mass distribution of positive ions. Simultaneous measurement of electron and ion concentration will resolve the question of the charge balance, or the neutrality, of the medium. Electron temperature data, when compared with kinetic gas temperatures obtained by other observers, will resolve the important question of thermodynamic equilibrium. If thermodynamic equilibrium is found to exist in the upper atmosphere, measurement of electron temperature might then be the most convenient method of studying temperature distributions in space. Studies of the ion mass distribution will establish the altitude of the base of the exosphere, and will be important to theories of magnetohydrodynamics.

A secondary objective is measurement of the charge accumulation on the satellite surfaces, which can be related to electrical

drag. Consequently, such charge-accumulation measurements are important to studies of the density of the medium, which is now being computed from satellite orbital decay observations that neglect electrical drag. This is particularly important because of the possibility of high satellite potentials in the Van Allen radiation belt.

Other secondary objectives of the satellite are the measurements of the frequency, momenta, and energies of micrometeorite impacts. The momentum range being scanned is considerably larger than that of previous satellites, and the energy measurement experiment is an improved version of one used earlier in a rocket flight. Comparison of the energy and momentum data permits separate determination of the masses and velocities of micrometeorite particles. Since satellite aspect is being measured, the velocity vectors of the particles also can be ascertained. Because of the low perigee, observations are being made of the effects of "sputtering" on the surface of the micrometeorite energy detector. ("Sputtering" is here used to mean erosion of the vehicle surfaces by impingement of all types of particles.)

Description of Experiments

Ionosphere probe 1960 Xi carries seven scientific experiments. The following is a description of the experiments, the equipment used, and the types of measurements made:

Radio-Frequency Impedance Probe: This experiment measures electron concentration by comparing the in-flight capacitance of the sensor, or the amount of electrical charge it will hold, with its free-space value. (The experiment is based on a rocket technique designed and tested by J. E. Jackson.) The sensor, located on the satellite's equator, is a shortened dipole antenna, each half of which is 10 feet long. A measurement of capacitance is made 25 times a second, permitting the experiment to search out ionospheric heterogeneities with dimensions of the order of 300 meters.

Single-Grid Ion Trap: In this experiments positive ion concentrations and mass distributions are measured using techniques very similar to vacuum-tube techniques. The ionosphere provides a near vacuum and also acts as the filament, or ionization source. It is only necessary then to provide a grid and a plate, or collector, to complete the construction of a vacuum tube in space, and with it to study ionization in the immediate vicinity of the satellite.

Multiple-Grid Ion Trap: The objectives and basic principles of this experiment are the same as those of the single-grid ion-trap experiment described above. Comparison of the single- and multiple-grid data will provide an evaluation of the effects upon the ion data of the ion sheath surrounding the vehicle. The accompanying instrumentation is common and time-shared; both experiments were calibrated against an earlier carrier-wave propagation experiment in vertical sounding rockets.

Langmuir Probe: In this experiment, electron temperature is measured by means of two sensors located diametrically opposite each other. Each sensor consists of a collector in the form of a circular plate flush with and insulated from the satellite skin. Both electron and positive-ion currents are measured.

Electric-Field Meter: This experiment determines the distribution of charge that accumulates on the satellite surface by measuring the electric field produced by the ion sheath that forms around the satellite. The sensor, located directly on the spin axis of the satellite, is termed a rotating-shutter-type electric-field meter. It measures electric fields up to 10,000 volts per meter and has a noise equivalent of less than 5 volts per meter.

Micrometeorite Photomultiplier: This experiment measures the light energy emitted as a micrometeorite impinges upon a surface and relates it to the ambient kinetic energy of the particle.

The sensor is a rugged, conventional, "end-type" 7151 C photomultiplier with a one-micron evaporated layer of aluminum on the front surface. A micrometeorite particle penetrating the aluminum coating registers its visible-light energy on the photocathode. The resulting pulse varies in length and amplitude as a function of the micrometeorite's kinetic energy. The maximum sensitivity of the sensor to light pulses is 10^{-3} erg.

Micrometeorite Microphone: In this experiment, the frequency and momentum of micrometeorite impacts are measured. The micrometeorite targets are two "sounding boards" located on the lower cone of the satellite and acoustically insulated from the satellite skin. Attached to each sounding board is a microphone that detects the impulse that occurs when a micrometeorite collides with the sounding board. By pre-flight calibration, the detected impulse can be related to the momentum of the incoming particle.

Telemetry and Power Sources

The telemetry system on satellite 1960 Xi operates continuously so that all data transmission is on the basis of real time. The system is a descendent of that used in the Vanguard program, in which the transmitted signal contains bursts of amplitude modulation separated by periods of no oscillation, or "blanks." The long-term average radiated power output during modulation is 100 milliwatts. At its base, the satellite has a linearly-polarized, quadriloop (clover leaf), 108-mc antenna similar to that used on 1959 Iota. The same antenna functions as the command receiver. For data acquisition, the required pre-detection receiver bandwidth is 50 kc. For this value, a pre-detection signal-to-noise ratio of 14 db at a 1000-mile range has been computed.

Mercury cells are used exclusively as power sources for the 1960 Xi experimentation. All experimental components are operated continuously except the electric-field meter, which is active for two-minute periods only on command. The total power consumption for this experiment is approximately 500 milliwatts. For this capacity and the expected frequency of command exercise, the experiments should be active for at least two months after launch.

Tracking and Data Acquisition

Since the telemetry transmitter operates continuously, a separate tracking transmitter is not included. The NASA Minitrack network provides the major portion of the long-term tracking information. The feasibility of using microlock for additional tracking information was established during prototype testing, and a number of these stations are also being used.

"Planet Earth" Film Series

The National Academy of Sciences has now completed its "Planet Earth" films. Produced under a grant from the Ford Foundation, the series consists of thirteen 16-mm, 27-minute educational films, available in both color and black-and-white, covering the principal fields of geophysical research stressed in the program of the International Geophysical Year.

Origin and Purpose

The film series, the first produced by the Academy, originated in the interest of students, teachers, and the general public in the IGY. The films synthesize man's knowledge of his physical environment, and also delineate newly-developed and powerful tools, such as rockets and satellites, for gathering data on space and the cosmos. Extensive film footage was made for the series in all parts of the world during and after the IGY, thus providing the viewer with the stimulus and interest of field work both at home and in distant places.

Although the inspiration for the program came from the IGY, the films give a rounded picture of man's quest for knowledge in each field, outlining the principal discoveries and ideas and raising questions that still challenge science with regard to the cosmos and the earth itself. The content, in any given field, while utilizing the striking results of the IGY, ranges from early to present-day ideas and experiments, with some projection into the future. Art and iconography are used to present ancient and early notions.

In the production of the films, specialists in each of the thirteen fields were called upon for guidance from all parts of the country and even abroad. Thus, the scientific soundness of the films was ensured. Because many of the ideas in geophysics are abstract, animation is used as needed. Live film coverage ranges from laboratory experiments to field activities. Film crews were sent to many parts of the world to show scientists at work, and how they work, in nature from the tropics to the poles. The legitimate adventure of man's coping with his environment and of scientists' seeking knowledge from nature is often reflected in the field work. Moreover, the planetary character of geophysical problems is revealed by the scenes from other countries and from remote regions like the Antarctic.

Contents

Of the thirteen films, three are devoted to the solid earth: "The Hidden Earth" (seismology), "The Shape of the Earth" (geodesy), and "The Force of Gravity." Three others explore the interface environment between the solid earth and the higher atmosphere: "The Inconstant Air" (weather and climate), "Secrets of the Ice" (glaciology), and "Challenge of the Oceans" (oceanography). Seven films are concerned with the upper atmosphere and space: "Our Nearest Star" (the sun and solar activity), "The Flaming Sky" (aurora), "Magnetic Force" (the earth's magnetic field), "Radio Waves" (including the ionosphere and radio astronomy), "Cosmic Rays," "Research by Rockets," and "Science in Space" (satellite and space-probe research). The following paragraphs briefly describe each film:

The Hidden Earth: The structure of the solid earth is analyzed—from the crust, through the mantle, to the central core. The dynamic quality of the "solid earth" is demonstrated through analysis of earthquakes and volcanoes. Application of seismology to the study of other planets is introduced.

The Shape of the Earth: The study of the size and shape of the earth is presented from ancient times to present concepts derived from data obtained from orbiting

satellites. Present efforts to refine and perfect man's knowledge of the shape of the earth are outlined and the relationship of this effort to future problems of navigation in space is explained. The determination of position and of distances on the earth by astronomical means is examined.

The Force of Gravity: The nature of gravitation is examined from early times to the present. The role of the gravitational field in accounting for the motions of planets is described. Newtonian and Einsteinian theories are explained and contrasted, and gravitational problems of the space age are introduced.

The Inconstant Air: Man's early efforts to measure pressure and temperature afford a basis for understanding the phenomena that make up both weather and climate. Circulation of the atmosphere is portrayed as well as the role of energy from the sun. How meteorological data are collected and how weather forecasts are arrived at are discussed. Theories on climatic changes and how they might come about are described. Current research in the laboratory and using satellite vehicles is presented.

Secrets of the Ice: The role of snow and ice in man's physical environment is explained. Mountain glaciers and ice fields of Greenland and Antarctica are explored with research parties. The relationship between glaciology on the one hand, and oceanography and weather on the other, is explained.

Challenge of the Oceans: The physical aspects of the ocean are examined, including the variety of currents in the ocean, the relationship of the dynamics of the oceans to weather and climate, and the composition of ocean waters. The life cycle in the oceans is sketched. Topography and composition of ocean bottoms is delineated and the structure and content of the sediments are portrayed.

Our Nearest Star: The properties of the sun and the relationship of solar activity to the earth are explained. Such events as sunspots and solar flares, which exert a profound influence on the earth's upper atmosphere, are portrayed. The effect on man's environment of particles and radiations from the sun is analyzed.

The Flaming Sky: The nature of the aurora—the mysterious northern and southern lights—is explored. The development of modern understanding of this phenomenon is traced from the ancient Romans to present beliefs that relate the aurora to emission of charged particles from the sun. The film examines present scientific thinking on what the aurora is, what causes it, and its relationship to other phenomena in man's physical environment, including the earth's magnetic field, radio waves, and solar activity.

Magnetic Force: The nature of the earth's magnetic field is explained, beginning with early speculations. The magnetic field within the earth and that existing in space are described. The film shows how the magnetic field controls the paths of cosmic-ray particles and of charged particles that make up the aurora. The manner in which magnetic force provides man with a better understanding of the earth and the far reaches of the universe is described.

Radio Waves: Both man-made and natural radio waves are discussed, beginning with the discoveries of Heinrich Hertz in the 19th Century. The influence of the ionosphere on radio waves is explained, and the relationship between radio waves, the ionosphere, the earth's magnetic force and solar activity is delineated. The new science of radio astronomy, which seeks to learn more about the universe from radio waves coming to the earth from elsewhere in our solar system and from space beyond it, is described.

Cosmic Rays: A detailed examination is made of present concepts of the origin and

nature of charged particles reaching the earth from outer space. Recent discoveries—using balloons, rockets, and satellites—are presented, and the relationship between cosmic-ray research and nuclear research is outlined.

Research by Rockets: The exploration of the upper atmosphere by instruments carried aloft in rockets is explained. The history of man's attempts to reach out into the higher atmosphere is portrayed and the variety of modern rocket vehicles, including their principles of operation, is shown. Significant discoveries relating to the atmosphere, ionosphere, the earth's magnetic field, cosmic rays, the aurora, and radiations from the sun are examined.

Science in Space: Scientific exploration of space and its contents and the placing of satellites into orbit are explained. Significant discoveries of modern space science are shown, including the Van Allen radiation belts. Radio and optical methods of tracking satellites, the telemetry of data from satellites and space probes to earth, and the analysis of these data are emphasized. The significance of satellites and space probes to man's understanding of the cosmos is stressed.

Production

Hugh Odishaw, of the National Academy of Sciences, acted as Director of the series and Lothar Wolff, of Louis de Rochemont Associates, Inc., served as Producer. The series was produced by the Academy in cooperation with the WGBH Educational Foundation, Cambridge, Massachusetts.

Over two hundred of the nation's leading geophysicists cooperated in the production of the films. To assist in their development, an Advisory Committee on Education (IGY) was established by the President of the Academy. This committee includes Wallace W. Atwood, Jr., Director of the Office of International Relations, National Academy of Sciences; James S. Coles, President, Bowdoin College; Carey Croneis, Provost, Rice Institute; Laurence M. Gould, President, Carleton College; J. Wallace Joyce, Head, Office for Special International Programs, National Science Foundation; Joseph Kaplan, Chairman, US National Committee for the IGY, National Academy of Sciences; John R. Mayor, Director of Education, American Association for the Advancement of Science; Hugh Odishaw, Executive Director, US National Committee for the IGY; Alan H. Shapley, Vice Chairman, US National Committee for the IGY; and Randall M. Whaley, Executive Secretary, Advisory Board on Education, National Academy of Sciences.

In addition to the foregoing, a working group, drawn from the US Office of Education, the National Science Teachers Association, the National Education Association, the National Academy of Sciences, and the National Science Foundation, advised on the production of the film series from the standpoint of stimulating interest in science in general and geophysics in particular.

Distribution

The Academy has concluded an agreement with the McGraw-Hill Book Company, Inc., to provide for distribution of the film series. In accordance with this agreement, McGraw-Hill will distribute the films, either severally or in sets, both in the United States and abroad, to educational and research institutions at the price of $80.00 for black-and-white prints and $150.00 for color prints. The entire series is now available for preview at McGraw-Hill Text-Films, 330 West 42nd Street, New York, New York.

Preprinted from *Transactions, American Geophysical Union,* Vol. 41, No. 4, December, 1960

THE UNIVERSITY OF ILLINOIS AT CHICAGO
3 8198 318 725 866